DEPOSITION AND POST-PROCESSING OF POLYCRYSTALLINE DIAMOND FOR FREESTANDING FILMS AND SUBSTRATES

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Abstract

High quality freestanding films and substrates of polycrystalline diamond with greater than 25 microns thickness have applications for windows, thermal heat sinks and stripping foils for high energy ion beams. Such applications of thick films or substrates require both deposition and post processing steps. In this paper we report on the synthesis of high quality diamond and the fabrication of optical quality windows and uniform thickness ion beam stripping foils. Both of these applications require the deposition of high quality diamond, the laser cutting of the diamond to a desired shape, the post processing of the diamond by etching, lapping and polishing steps to produce smooth, flat and uniformly thick films or substrates. The thickness of the diamond films needed for the ion beam stripping foils are up to 40 μm.

The polycrystalline diamond films are grown in a microwave plasma-assisted CVD reactor using hydrogen/methane chemistry. The methane percentage is nominally 1 %. The deposition reactor is a microwave cavity applicator with the plasma confined inside a 12 cm diameter quartz dome [1]. The substrates utilized are 1 and 2 inch silicon wafers with thickness in the range of 1-2 mm. The substrate is actively cooled with a water cooled substrate holder to achieve a substrate temperature of 850-950 C. The pressure utilized is 120-180 Torr and the microwave power is 3.5-5 kW. The substrate holder is designed to achieve a reasonable uniform substrate temperature distribution. The silicon substrates are prepared using mechanical polishing with diamond powder for nucleation. The growth rate of the polycrystalline diamond is approximately 1 μm/hr at 120 Torr. Influence of the deposition chemistry and reactor configuration on substrate temperature and deposited film uniformity will be presented. Additionally, initial modeling studies to understand the substrate temperature uniformity and control will be shown.

Once the diamond is deposited on the silicon substrate a number of post processing steps are performed to fabricate smooth, flat and uniformly thick films or substrates. These processing steps typically include laser cutting, lapping and polishing of the growth side of the diamond, removal of the silicon substrate, and plasma etching to remove a thin layer on the nucleation side of the diamond film. Laser cutting is performed with a pulsed Nd-YAG laser operating with the third harmonic. Lapping and polishing is performed with a Logitech LP 50. The polishing system has been used to achieve surface roughness values of 3 nm. During the post processing of the diamond film the bowing (stress) of the film is characterized at various steps. The diamond films/substrates are also characterized at the end of the post-processing a number of ways including Raman spectroscopy, photoluminescence spectroscopy, and optical absorption.

A challenge to the fabrication of flat and uniform films/substrates is dealing with the intrinsic stress of the diamond film. When the film is deposited on a silicon wafer a bowing of the wafer and diamond film occurs due to the thermal expansion mismatch of at the diamond-silicon interface and due to intrinsic stress in the diamond film itself [2, 3]. Once the diamond is removed from the silicon substrate by etching the silicon away, the diamond film bowing is due to stresses within the diamond film itself. A gradient in the stress within the diamond film in the direction of growth leads to a bending of the freestanding film. Techniques to compensate for this bowing that include removal of a layer of the film on the nucleation side are explored.

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